JACC Vol. 8, No. 1
July 1986:67–75

METHODS

Phase Analysis of Gated Blood Pool Scintigraphic Images to Localize Bypass Tracts in Wolff-Parkinson-White Syndrome

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The ability of radionuclide techniques to localize bypass tracts in patients with Wolff-Parkinson-White syndrome to sites around the atrioventricular (AV) ring using a three view triangulation method was investigated. In 17 patients with Wolff-Parkinson-White syndrome, phase images were generated from gated blood pool scans using the first Fourier harmonic of the time-activity curve of each pixel. In addition, the difference between left and right ventricular mean phase angles was calculated for each patient and for 13 control subjects. Bypass tracts were localized to one or more sites on a 10 site grid schematically superimposed on the AV ring (Duke grid) by electrophysiologic study in all patients and by intraoperative mapping in 7 of the 17 patients. These same 10 anatomic sites were projected onto three scintigraphic views and the site of earliest ventricular phase angle was located in each view.

The 10 sites around the AV ring were divided into two anatomic groups: free wall and septal/paraseptal. Phase image locations correlated with electrophysiologic locations within one grid site in 11 of 11 patients with free wall tracts and were confirmed at surgery in 5 of the 11. In five of six patients with septal/paraseptal tracts, electrophysiologic study could not localize the bypass tract to one site, whereas phase images localized two of the five as free wall adjacent to the septum, one as paraseptal and two as true posteroseptal. One posteroseptal site was confirmed at surgery. In one patient, in whom phase image analysis and electrophysiologic study showed different sites, existence of both tracts was confirmed at surgery. This triangulation method may be a useful adjunct for preoperative localization of bypass tracts in patients with Wolff-Parkinson-White syndome.

(J Am Coll Cardiol 1986;8:67–75)

Electrocardiographic and electrophysiologic approaches have both been used to localize bypass tracts to anatomic sites in patients with the Wolff-Parkinson-White syndrome. Delta wave vector analysis has resulted in a helpful electrocardiographic schema as described by investigators at Duke University (1). In this method the ventricles at the level of the atrioventricular (AV) ring are represented schematically, and using the mean vector of the first 40 ms of the delta waves recorded on a 12 lead electrocardiogram, 10 bypass tract sites around the ring are anatomically localized. From this anatomic grid a bypass tract may be localized to 1 of 10 regions. From the electrocardiogram alone multiple tracts or tracts that conduct retrograde only cannot be identified.

Electrophysiologic mapping can further enhance bypass tract localization and can identify multiple tracts (2). However, precise electrophysiologic mapping is not always achieved because of factors such as difficulty in catheter placement and failure of tracts to conduct retrograde. For anterior paraseptal tracts, the left atrium is inaccessible to direct catheter mapping without using a transseptal approach. For posterior paraseptal tracts, in the region of the crux, the paraseptal and right posterior regions are anatomically close and may be indistinguishable by electrophysiologic mapping. Consequently, techniques offering complementary data would be of value.

Functional images called phase images may be generated from gated blood pool scans. The phase image values are the phase angles obtained from first harmonic Fourier transforms of the time-activity curves for each pixel in the original image series. Previous studies (3–6) have shown that phase images can characterize abnormal patterns of ventricular activation. In addition, several previous studies (7–10) have shown that phase images can provide information regarding the site of bypass tracts in patients with the Wolff-Parkinson-White syndrome.

None of the previous studies have focused on the potential clinical utility of the addition of phase image localization to electrophysiologic mapping for preoperative evaluation

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Manuscript received December 2, 1985; revised manuscript received February 19, 1986, accepted March 5, 1986.

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0735-1097/86/$3.50

JACC Vol. 8, No. 1
July 1986:67–75

of patients with Wolff-Parkinson-White syndrome. In addition, the present study is the first to use a three view triangulation method for improved localization of bypass tracts.

Methods

Patient selection. Seventeen consecutive patients referred to our electrophysiology laboratory for study of Wolff-Parkinson-White syndrome underwent a gated blood pool scan. There were 15 male and 2 female patients with a mean age of 33 ± 14 years (range 15 to 56). All patients had gated blood pool scans within 48 hours of electrophysiologic study. In addition, 13 control subjects were studied. The control group comprised patients without pre-excitation or ventricular conduction disturbances who had a gated blood pool scan before receiving adriamycin therapy. There were six men and seven women with a mean age of 33 ± 7 years (range 21 to 40). All were without history of heart disease and had a normal electrocardiogram, chest X-ray film and physical examination of the heart.

Electrophysiologic study. Patients undergoing electrophysiologic study were studied in the fasting, nonsedated state after informed consent was obtained. From the femoral or basilic vein, or both, percutaneous cardiac catheterization with three or more 6F to 7F multipole electrode catheters was achieved after lidocaine local anesthesia and sterile skin preparation. The catheters were positioned fluoroscopically and electrographically so as to record or stimulate as many of the following sites as were feasible in each patient: right atrial appendage, right ventricular apex, His bundle region, low anteromedial right atrium, low anterior right atrium, low posterolateral right atrium, low posterior right atrium, low posteromedial right atrium (the right AV ring) and (through the coronary sinus) the proximal, midproximal, mid, midlateral and lateral left atrium. The low anterior and anterolateral left atrial portion of the AV ring could be recorded only in one of the two patients with a patent foramen ovale. The left side of the atrial septum could not be recorded directly. Recordings of the left atrial roof, through the left pulmonary artery, were obtained when considered necessary. A typical sample of recordings from these regions obtained in our laboratory has been previously published (2).

The bypass tract identified by the electrophysiologic study was then assigned one or more bypass tract numbers corresponding to the same anatomic regions on the Duke grid used for electrocardiographic localization (1). Because of technical difficulties in catheter placement in some sites, especially in the region of the anterior septum, it is not possible in the electrophysiology laboratory to identify a true anteroseptal site. Therefore, tracts localized to the anteroseptal/paraseptal region are designated as right anterior paraseptal or left anterior paraseptal tracts. In addition, it is frequently difficult to separate a right anterior free wall tract from the left and right paraseptal sites. The posterior paraseptal region is accessible to catheter mapping due to proximity of the coronary sinus. However, because stable catheter placement near the opening to the coronary sinus is difficult, the right posterior free wall, true posteroseptal and right posterior free wall sites, which are located close together near the opening to the coronary sinus, are also difficult to separate by electrophysiologic study.

Multiple methods of bypass tract localization were utilized during electrophysiologic study. Our approach to such localization (or mapping) is reviewed in detail elsewhere (2). It includes the following:

1. Pacing multiple atrial sites along the AV ring (sequentially) at multiple cycle lengths (800, 700, 600, 500, 400 and occasionally 350 to 250 ms) to determine the site that maximizes ventricular pre-excitation (assessed electrocardiographically by timing of His bundle depolarization and by characteristics of intracardiac electrograms).
2. Recording from multiple sites along the AV ring during reentrant AV tachycardia or during right ventricular pacing, or both (to assess location of ectopic atrial activation).
3. Assessing regional atrial activation timing during retrograde refractory period determination and assessing the effects of induced bundle branch block on cycle length and retrograde atrial activation time during reentrant AV tachycardia (to determine characteristics and lateralization of tracts).

Intraoperative mapping. In eight patients, intraoperative mapping studies (2,11) were performed to guide ablative surgery. In one patient (Case 15) surgical mapping was not successful. *Our protocol, as detailed elsewhere (2), includes:*

1. Epicardial mapping around the AV ring on the ventricular side during anterograde pre-excitation (with atrial pacing if necessary) and on the atrial side during paroxysmal supraventricular tachycardia or during ventricular pacing, or both.
2. Endocardial mapping around the tricuspid and mitral valve rings on the ventricular side during anterograde pre-excitation (with atrial pacing if necessary) and on the atrial side during paroxysmal supraventricular tachycardia or during ventricular pacing, or both. The sites of bypass tract insection as determined from the regions of earliest activation are identified.

Gated blood pool scintigraphy. The patient's red blood cells were labeled with 20 to 30 mCi of technetium-99m pertechnetate using a modified in vivo method (12). Images were obtained in the left anterior oblique projection that best demonstrated the interventricular septum in the anterior view and in either a left lateral or a left posterior oblique view. Foreshortening of the ventricular chambers was minimized by using a 30° slant-hole collimator. Images were acquired with a nuclear medicine computer system (MDS) having a 64 × 64 matrix and software zoom (1.5×), using a framing

interval calculated to produce 28 frames/cycle. Each study was acquired to a total of 250,000 counts/frame. Left ventricular ejection fraction was calculated using commercially available software (MDS). Regional wall motion was assessed quantitatively using the method of Burow et al. (13).

Image processing and phase analysis. The number of counts in each frame of the study was determined, and terminal frames containing less than 95% of the average counts (determined over the first half of the study) were excluded. The remaining frames were temporally and spatially smoothed and first harmonic Fourier phase and amplitude images were generated using commercially available software (MDS). These images were inspected visually, utilizing a dynamically changing gray scale that highlighted the individual pixels with any given phase angle. In addition, left and right ventricular phase angle distributions were examined quantitatively. An initial region of interest was drawn around each ventricle using the smoothed end-diastolic gated image. These regions were then projected onto the amplitude images and modified to exclude areas of the ventricle with relative amplitudes of less than 20%. Phase histograms were compiled for the selected regions, consisting of the number of pixels with a given phase angle plotted against the phase angle. To minimize noise, low values in the left and right ventricular histogram curves, away from the main peaks, were set at zero. This was done for all points beyond the first point which was less than 5% of the maximum of the combined histogram curve, similar to the method of Botvinick et al. (10). Mean phase angles were then computed from the resulting ventricular histograms, and differences between the left and right ventricles were compared.

Method of bypass tract localization. To achieve precise localization of the accessory conduction pathways visually, we overlaid a two-dimensional projection of each of the 10 AV ring bypass tract sites in the Duke classification (1) onto representations of our standard gated blood pool views (Fig. 1). The region in which the dynamic gray scale images showed the pixels with the earliest phase angles was taken as the bypass tract site. On a single gated blood pool image the area of earliest phase might correspond to more than one site, depending on closeness or overlap of adjacent sites in that view, but by using three views a unique common site could be localized. Only the single location that was common to all three views was considered to be the site of the patient's bypass tract. The left anterior oblique view provided the best separation between left- and right-sided tracts and for determining whether the tract was lateral or medial. The left lateral or left posterior oblique view clearly separated anterior from posterior tracts. The anterior view provided additional information differentiating right versus left and lateral versus medial location. Because the septum is usually not visualized as a distinct structure on phase images, a tract was localized in anatomic relation to the septum by its position on the valve plane and by direct

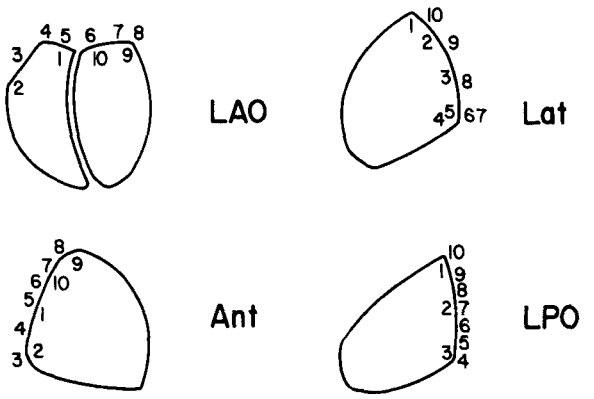

Figure 1. Anatomic grid of bypass tract sites projected onto scintigraphic scans in four views. 1 = right anterior paraseptal; 2 = right anterior; 3 = right lateral; 4 = right posterior; 5 = posteroseptal; 6 = left posteromedial; 7 = left posterior; 8 = left posterolateral; 9 = left anterolateral; 10 = left anterior paraseptal. The combined sites 10, 1 and 2 are designated as anterior paraseptal and sites 4 to 6 are designated as posterior paraseptal. Ant = anterior; LAO = left anterior oblique; Lat = lateral; LPO = left posterior oblique.

comparison with the gated study cine display. Localization of each bypass tract from the set of phase images was performed by two independent observers who were unaware of the electrocardiogram or electrophysiologic results.

Statistical analysis. Mean phase angle data were analyzed using an analysis of variance. The significance of differences for the means among groups was assessed using the Bonferroni method.

Results

Control patients. Thirteen control patients who had gated blood pool scans for baseline prechemotherapy measurement had analysis of phase images and phase histograms. The mean ejection fraction was 71 ± 10%. There was no significant difference between the two ventricles in mean phase angle (mean difference 0.57 ± 3.0). The earliest site of ventricular activation in all patients corresponded to the region between zone 1 and zone 10 on the grid (anterior septum). (Fig. 2).

Patients With Pre-excitation

Ejection fraction. The mean ejection fraction for all 17 patients was 61 ± 10%. The ejection fraction values were greater than 50% for all except one patient, in whom the value was mildly reduced (45%). Regional ejection fraction values were within 2 standard deviations of the normal mean for all patients in the pre-excitation group. These 17 patients were divided into two groups on the basis of electrophysiologic criteria: septal/paraseptal and free wall.

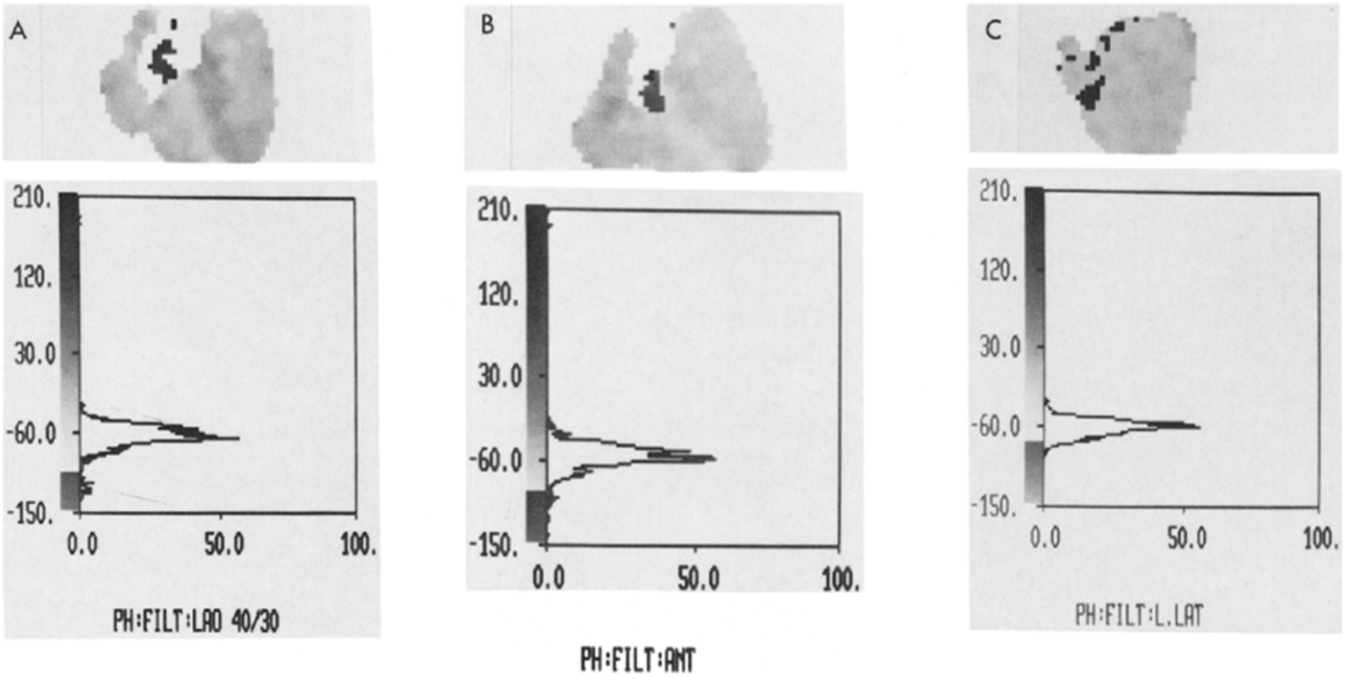

Figure 2. Control patient. **Panels A, B** and **C** show phase images (**top**) and ventricular phase histograms (**bottom**). On each panel, the phase histogram (PH) shows the range of phase angles on the y axis and the number of pixels in the phase image with each phase angle on the x axis. The gray scale has been selected to highlight those pixels with earliest ventricular phase angles in dark gray. The anatomic sites of earliest ventricular activation were localized to grid sites 1 or 5 in the left anterior oblique (LAO) view (**A**), to grid site 1 in the anterior (ANT) view (**B**) and grid site 1 in the left lateral (L.LAT) view (**C**). FILT = filtered.

Septal/paraseptal tracts. Six patients had a bypass tract located within the septal/paraseptal region (grid sites 10, 1 and 2 and 4 to 6) by electrophysiologic study (Table 1). In four of these cases the electrophysiologic study could only identify the bypass tract as anterior (Fig. 3) or posterior (Fig. 4) because of limitations in catheter placement, and in a fifth patient the study identified the tract site as either the posterior septum or left posterior paraseptal region. The phase image analysis in all five agreed with the electrophysiologic classification of an anterior or posterior site but was able to localize the tract to a single site. Intraoperative mapping was performed in Patient 4 (Fig. 4) and the phase image localization to the posterior septum (site 5) was confirmed. The mean ventricular phase difference in this patient was relatively large (+14.8). This large difference in phase angles between the two ventricles was evidently due to abnormal activation of the conducting system from the septal bypass tract. Patients 2 and 3 also showed a large positive difference in left and right ventricular mean phase angles (+29.0 and +36.9, respectively) and had a site by phase image analysis localized to the right anterior free wall (Fig. 3). Neither of these two patients went to the operating room for mapping.

In Patient 6 the electrophysiologic study localized the bypass tract in the posterior septum (grid site 5). At the time of the gated blood pool scan the delta wave pattern on the surface electrocardiogram had changed from the time of the electrophysiologic study. The phase images in this patient placed the bypass tract site in the right anterior free wall region. Because of the image findings, the right anterior free wall region, in addition to the posterior septum, was carefully mapped at surgery. Two bypass tracts were found, one in the posterior septum as found by the electrophysiologic study and one in the right anterolateral region, confirming the phase image results as well as the electrophysiologic results. Because so many patients in the electrophysiology-designated septal/paraseptal group had large positive values for the difference between left and right ventricular mean phase angles, the group mean of $+18.6 \pm 17.7$ was significantly greater than that of control subjects ($p < 0.01$).

Free wall tracts. Eleven patients had a bypass tract localized to the free wall, nine left-sided and two right-sided (Table 1). The correlation between electrophysiologic bypass tract site localization and phase image localization was excellent and the site localization was confirmed by intraoperative mapping in five patients. For the left-sided tracts the difference in mean phase angles between the left and right ventricles was negative in all but one patient. The group mean for the difference between left and right ventricular mean phase angles for patients with a left-sided free wall tract was -8.5 ± 12.1. This value was not signifi-

Table 1. Summary of 17 Cases

Case	Bypass Localization by EPS	Bypass Localization by GBPS	$\overline{\Delta\theta}$(LV-RV)	Bypass Localization at Surgery
		Septal/paraseptal		
1	Ant paraseptal (10, 1, 2)	L ant paraseptal (10)	−5.0	
2	Ant paraseptal (10, 1, 2)	R ant (2)	+29.0	
3	Ant paraseptal (10, 1, 2)	R ant (2)	+36.9	
4	Post paraseptal (4–6)	Posterosep (5)	+14.8	Posterosep (5)
5	L post paraseptal (5,6)	Posterosep (5)	+1.4	
6	Posterosep (5)	R ant (5)	+34.7	Posterosep (5) plus R lat (3)
		Free wall		
7	L anterolat (9)	L anterolat (9)	−3.2	L lat (8, 9)
8	L anterolat (9)	L anterolat (9)	−10.7	L anterolat (9)
9	Rapid breakthrough (6–9)	L posterolat (8)	−4.1	
10	L anterolat (9)	L lat (8, 9)	+3.8	
11	L anterolat (9)	L lat (9)	−7.1	L lat (8, 9)
12	L anterolat (9)	L anterolat (9)	−0.7	L lat (8, 9)
13	L posterolat (7, 8)	L lat + R lat (8, 9, 3)	−2.5	L posterolat (7, 8)
14	L posterior (7)	L posterior (7)	−15.1	
15	L posterior (6,7)	L posterolat (7, 8)	−37.2	*
16	Rapid breakthrough R posterolat (3, 4)	R lat (3)	+16.4	
17	R post (4)	R post (4)	+10.5	

*Intraoperative mapping not successful. Ant = anterior; anterolat = anterolateral; EPS = electrophysiologic study; GBPS = gated blood pool scan; L = left; lat = lateral; Post = posterior; posterolat = posterolateral; posterosep = posteroseptal; R = right; $\overline{\Delta\theta}$(LV-RV) = difference in left and right ventricular mean phase angles. Numbers in parentheses refer to grid site locations around map of atrioventricular ring (see text).

cantly different from control ($p = 0.55$) due to the large degree of variability. Both patients with a right-sided free wall tract had large positive values for the difference between left and right ventricular mean phase angles. When the three patients from the electrophysiology-designated septal/paraseptal group whose phase image analysis indicated a right-sided tract (Cases 2, 3 and 6) were grouped with the two patients who by both methods were designated to have a right free wall tract (Cases 16 and 17), the group mean for the difference between left and right ventricular mean phase angles was $+25.5 \pm 11.6$, significantly greater than that of control subjects ($p < 0.01$).

The electrophysiologic and intraoperative studies in Patient 15 were incomplete. This patient's bypass tract conducted anterograde only. Rapid atrial pacing produced rapid atrial fibrillation and ventricular fibrillation. For safety, it was decided not to atrially pace from multiple sites around the AV ring in an attempt for more precise localization. Because the bypass tract conducted anterograde only, ventricular pacing was not useful. At surgery, conduction over the bypass tract could not be induced when the heart was lifted. Therefore, the surgeon used the combined results of the electrophysiologic and phase studies to guide surgical resection of the tract. The patient has not shown recurrence of pre-excitation postoperatively.

Pre- and postoperative studies. All eight patients who went to the operating room for intraoperative mapping and bypass tract resection had repeat gated blood scans performed postoperatively (Fig. 5). In seven patients the delta waves disappeared postoperatively and the bypass tract seen on initial phase mapping was no longer present. Patient 13 had recurrence of pre-excitation. Both electrophysiologic and phase image studies showed recurrence of a left posterolateral tract.

Discussion

This paper confirms the findings of previous studies (7–10) on the usefulness of phase image analysis to localize the site of bypass tracts in patients with Wolff-Parkinson-White syndrome. We have extended the findings of previous studies by utilization of a triangulation method to localize bypass tracts to small regions by scanning all patients in three views. A scan in any single view is a two-dimensional projection of a three-dimensional object. In two orthogonal views (anterior and lateral) the tract was localized along two axes (anterior versus posterior and left versus right) and in the left anterior oblique view the tract was localized to one side of the septum.

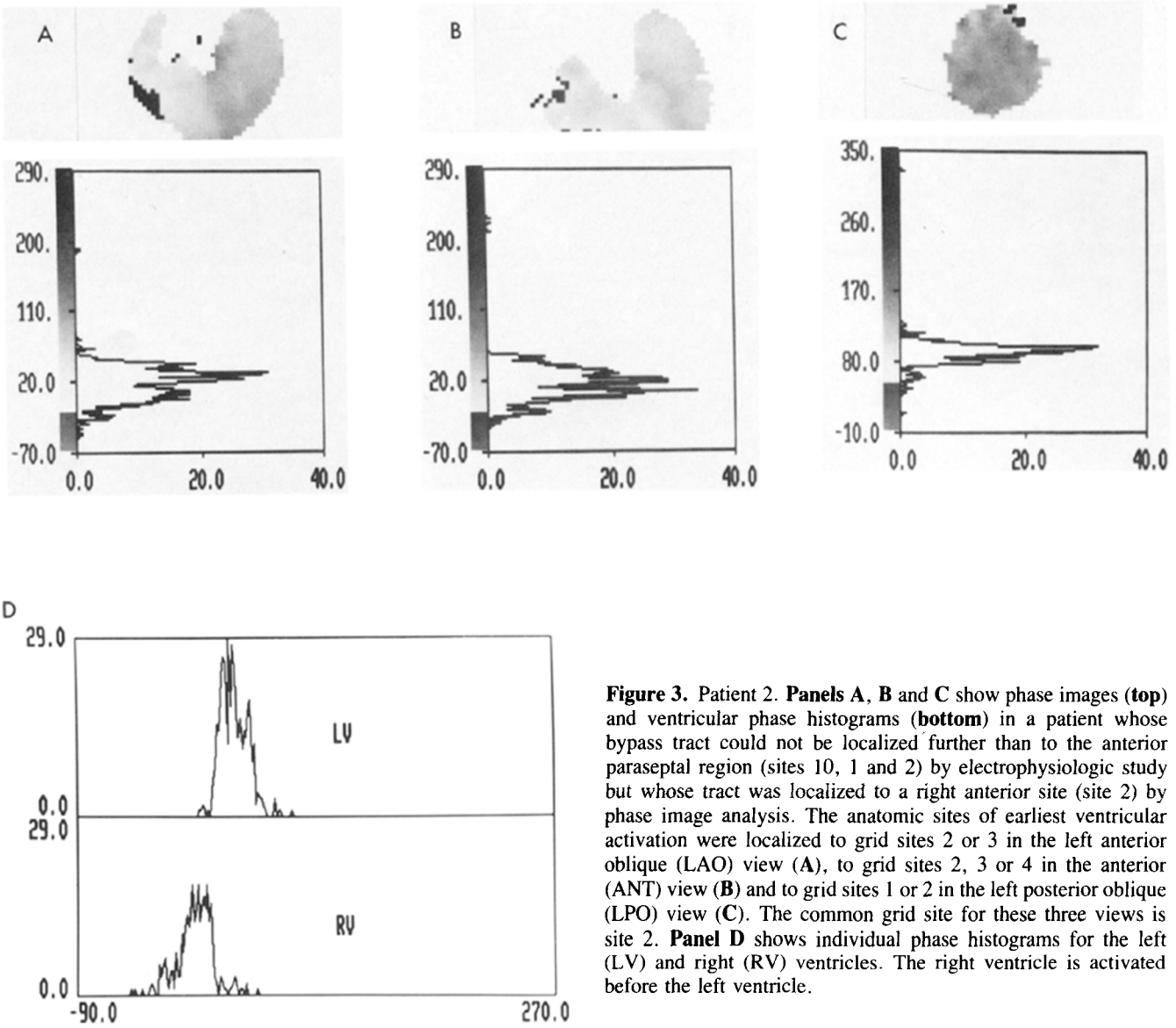

Figure 3. Patient 2. **Panels A**, **B** and **C** show phase images (**top**) and ventricular phase histograms (**bottom**) in a patient whose bypass tract could not be localized further than to the anterior paraseptal region (sites 10, 1 and 2) by electrophysiologic study but whose tract was localized to a right anterior site (site 2) by phase image analysis. The anatomic sites of earliest ventricular activation were localized to grid sites 2 or 3 in the left anterior oblique (LAO) view (**A**), to grid sites 2, 3 or 4 in the anterior (ANT) view (**B**) and to grid sites 1 or 2 in the left posterior oblique (LPO) view (**C**). The common grid site for these three views is site 2. **Panel D** shows individual phase histograms for the left (LV) and right (RV) ventricles. The right ventricle is activated before the left ventricle.

Comparison of bypass tract localization by three methods. The correspondence between site location number identified by electrophysiologic study, phase analysis and intraoperative mapping when available was excellent for the patients with right or left ventricular free wall bypass tracts. However, the septal/paraseptal region localization of bypass tracts by electrophysiologic study was unsatisfactory because of technical difficulties in catheter mapping. Anteriorly, the anterior left atrium is inaccessible except by transseptal approach, which is rarely used. Even when the left atrium can be directly catheterized through a patent foramen ovale, positioning of the catheter tip along the AV ring may not be feasible. Posteriorly, in the region of the crux, the tract sites lie very close together near the orifice of the coronary sinus, making it difficult to record from each site individually. In these cases, localization of bypass tracts in the electrophysiology laboratory was incomplete and the tracts could only be designated as anterior (zones 10, 1 and 2) or posterior (zones 4 to 6) paraseptal (Cases 1 to 4).

Using the triangulation method, anatomic localization to an anterior right-sided free wall site was made in two patients whose tracts could not be precisely localized by electrophysiologic study and who had a large positive difference between left and right ventricular mean phase angles, and to a posteroseptal site in two patients in whom electrophysiologic study could not localize the tract to a single site. In one patient the posteroseptal location was confirmed at surgery.

These results in the paraseptal group are preliminary because of the small number of patients and lack of intraoperative mapping in most cases. Because the electrophys-

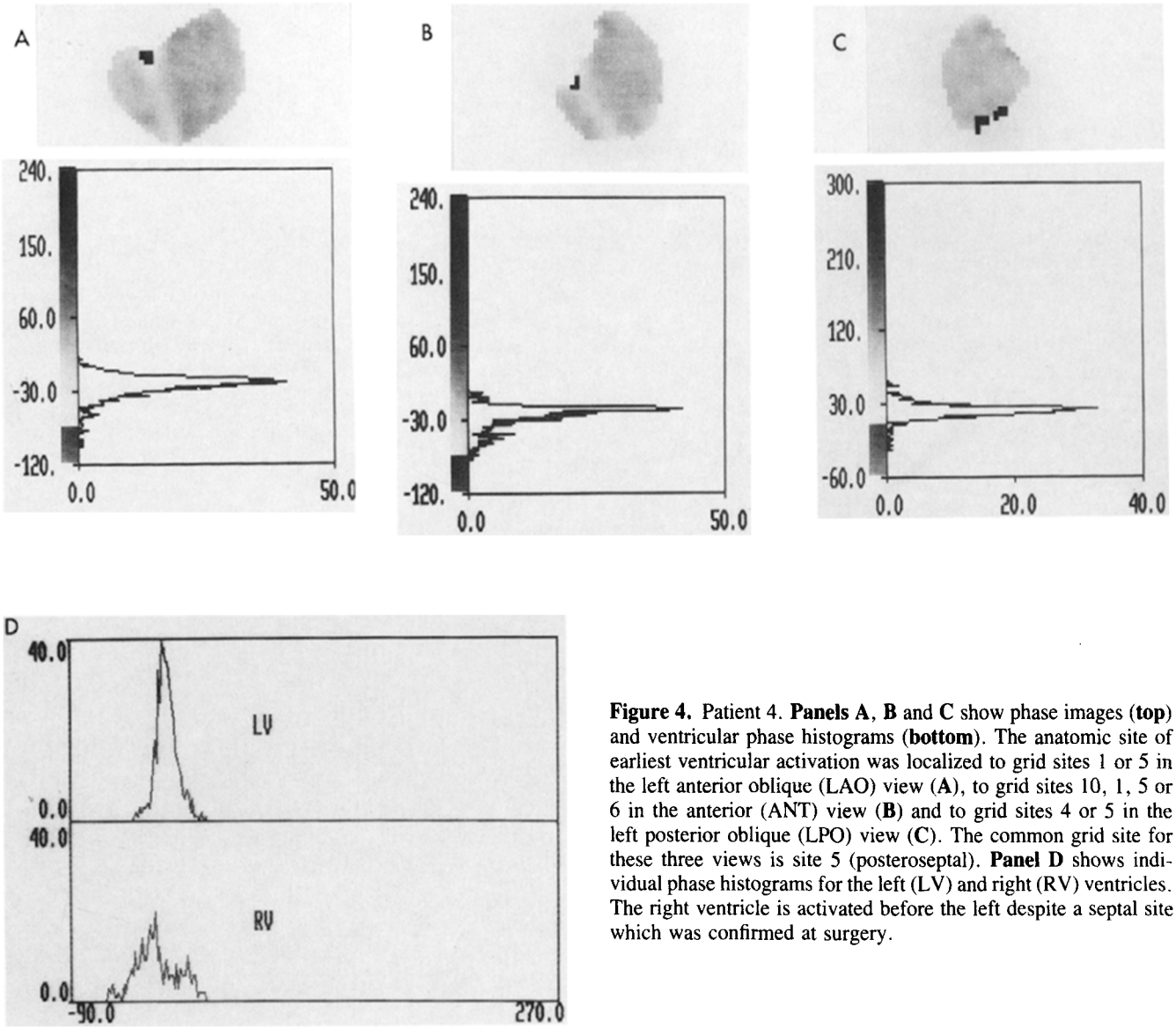

Figure 4. Patient 4. **Panels A, B** and **C** show phase images (**top**) and ventricular phase histograms (**bottom**). The anatomic site of earliest ventricular activation was localized to grid sites 1 or 5 in the left anterior oblique (LAO) view (**A**), to grid sites 10, 1, 5 or 6 in the anterior (ANT) view (**B**) and to grid sites 4 or 5 in the left posterior oblique (LPO) view (**C**). The common grid site for these three views is site 5 (posteroseptal). **Panel D** shows individual phase histograms for the left (LV) and right (RV) ventricles. The right ventricle is activated before the left despite a septal site which was confirmed at surgery.

iologic study is incomplete, intraoperative mapping becomes the reference standard with which to compare the results of the phase image analysis. A conclusion from these data requires surgical confirmation in all patients.

One additional patient had two tracts confirmed at surgery. At the time of the electrophysiologic study only the posteroseptal tract conducted, whereas at the time of the gated blood pool scan, only the right anterior free wall tract conducted. The coexistence of posteroseptal and right-sided bypass tracts has been reported (14).

Comparison with previous studies. Although the results of this study for patients with free wall tracts agree with the findings of previous studies (7–10), there are several apparent differences for the patients with septal/paraseptal tracts which deserve further comment and explanation. In the study by Botvinick et al. (10) there were no significant differences between mean left and right ventricular phase angles for either individual patients or the group with a septal pathway, whereas there were significant differences in mean ventricular phase angles in our septal/paraseptal group. There are several explanations for these apparent differences in results.

In this study by Botvinick et al. (10) the sites of bypass tract localization were classified according to mean ventricular phase differences and phase image localization and not by electrophysiologic localization as in our current study. If we had classified patients according to bypass tract sites identified by gated blood pool scintigraphy, then three patients from our septal/paraseptal group would have been reclassified as belonging to the right ventricular free wall group (Cases 2, 3 and 6). Of the three remaining patients in our septal/paraseptal group identified as having a true septal tract by both techniques, only one (Case 4) had a significant difference between left and right ventricular phase

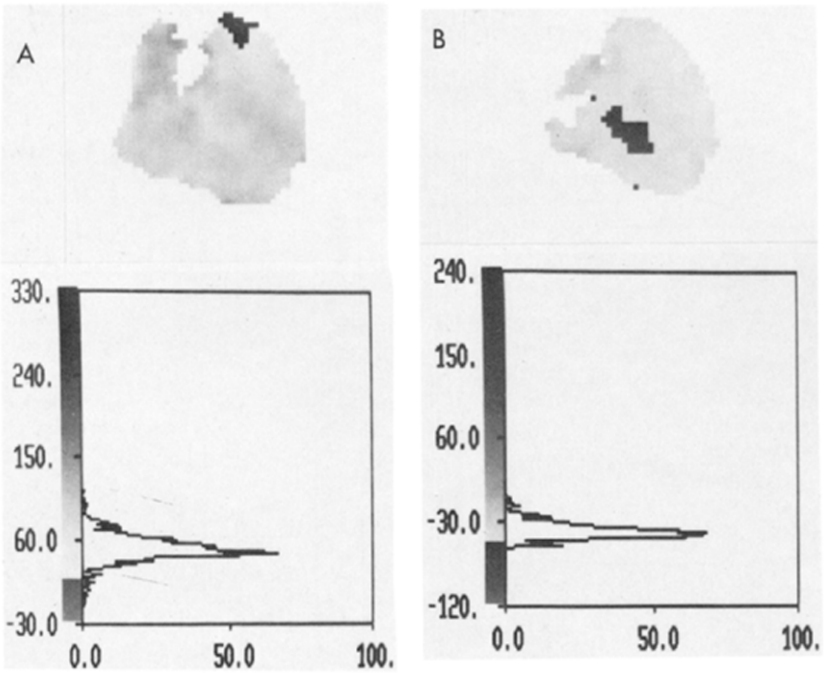

Figure 5. Patient 12. **Panels A** and **B** show phase angles (**top**) and ventricular phase histograms (**bottom**) before and after surgical bypass tract division (the anterior [ANT] scan only is shown). In **panel A** (preoperatively) the site of earliest ventricular activation was localized to grid site 9 (left anterolateral). In **panel B** (postoperatively) the site of earliest activation was localized to site 1 (anteroseptal).

angles. In this patient, the relatively large difference in phase angles between the two ventricles could represent preferential access to the right conducting system or could be due to technical factors. If the two ventricular regions were not correctly chosen or the best septal separation was not obtained at the time of acquisition, then there would be overlap of the two ventricles giving erroneous values for the mean ventricular phase angle of each ventricle and for their resultant differences. Every effort was made to avoid these errors but we cannot totally exclude the possibility that technical factors could have led to the large phase differences in this patient.

Whether or not Patient 4 is truly an example of an exception, there are nevertheless patients with septal pathways that may break into the left or right conduction system preferentially, giving rise to significant differences in phase angles between the two ventricles. Even considering these examples, however, the weight of current evidence continues to support the contention that most cases with preexcitation that demonstrate the site of earliest phase angle to be in the septum show little difference in mean ventricular phase angles. The phase angle data for the two remaining patients in our study with septal pathways identified by gated blood pool scintigraphy support these observations.

Limitations of the technique. There are several other limitations inherent in phase angle analysis. First, time-activity curves for each pixel are fit to simple cosine curves which are not truly representative of the more complex composition of the true data, especially during diastole. However, because systole is the major determinant of early phase angles, the incongruities between the true data and fitted cosine curves are less severe. Another limitation is the potential for inclusion of overlying structures, such as the atria or background regions outside the ventricular borders in the ventricular phase angle analysis. We used a 30° caudal angulation (slant-hole collimator) to minimize the atrial-ventricular overlap. We also excluded background noise by analyzing only those phase angles within the ventricular region of interest and excluding from analysis phase angles less than 5% of the maximal combined ventricular histogram.

Regional dysynergy unrelated to conduction abnormalities might alter phase angles in the distribution of the abnormally contracting segment. For this reason we performed quantitative regional wall motion analysis on all patients with the Wolff-Parkinson-White syndrome. Only one of our patients had a mildly reduced left ventricular ejection fraction and values for regional ejection fractions were within 2 standard deviations of the normal values for our laboratory. Fourier phase images may also be affected by translational and rotational motion of the heart (15). These motions predominantly affect amplitude and phase angle results for the septum, causing parts of this region to be excluded from analysis. Postoperative studies were most subject to this error, because septal wall motion abnormalities are frequently seen after surgery. However, the triangulation of the site of earliest phase activation does not seem to be affected, perhaps because multiple views are obtained.

Conclusions. These data suggest that bypass tract site localization in patients with Wolff-Parkinson-White syn-

drome from phase image analysis using the triangulation method agrees well with site localization by electrophysiologic study and intraoperative mapping. Preliminary data from only a few cases suggest that mapping the paraseptal region, which is frequently incomplete in the electrophysiologic laboratory, may be aided by phase image analysis and that patients with multiple tracts who conduct over different tracts at different times may be identified by this noninvasive method that can be performed serially as conduction patterns at rest change.

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